Understanding the features that determine dripper quality

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When comparing technical dripper data, we are confronted by terms that describe certain engineering features, namely K (A); X (B); KD; K (Turbulence coefficient) and Filtration area. These terms and the features they represent determine how well a dripper does its job. Understanding them enables us to compare how different drippers do the same job.

In this article I will discuss each of the terms listed below, how they interact and their impact on dripper quality.

- K (Turbulence coefficient)
- Filtration area (EFA)
- K (A)
- X (B)
- KD

Keeping a dripper clean

In my previous article, A system for dripper comparison, in the June 2019 edition of the SABI magazine, I reminded the irrigation industry that a farmer and his crop care not about the specifics of a dripper. Their only concern is what the dripper delivers. They need a dripped supply of water into the root-zone of the plant, on demand, over the lifespan of the crop. This dripped supply must never vary or decrease over time. It must be accurate and constant over the crop's lifespan.

If we understand this, we understand what contributes to a quality dripper. A quality dripper can be defined as one that emits a predetermined flow rate that is accurate and constant over its intended lifespan. To ensure this, essentially the dripper needs to be kept clean.

Keeping a dripper clean, involves the first two aspects above:

- K - turbulence coefficient
- EFA - effective filtration area

Understanding the Turbulence Coefficient

Any dripper has:

- a flow rate - normally between 1 ℓ/h and 2 ℓ/h
- an inlet pressure – normally 1 bar (can be over 3 bar in PC)
- an outlet pressure – always 0 bar

To emit 1 ℓ/h, a dripper must reduce its inlet pressure from 1 bar to 0 bar. Essentially, pressure loss must occur. To make this possible, something must happen between the inlet pressure and the outlet pressure.

An easy way to facilitate this pressure loss, would be to simply make a hole in the pipe. This hole would have a diameter of approximately 0.17 mm. This is a mere pinprick, approximately the width of a strand of hair. A simple hole in the pipe would produce a jet of water, rather than a dripped supply of water. This hole would very easily be clogged by particles in the water supply.

Another way to facilitate this pressure loss, would to be to create friction loss through a small pipe. This is made possible by the fact that pressure is lost as water travels down a pipe. (See figure 1 below)

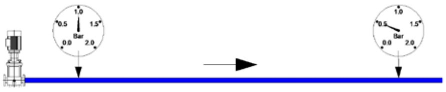

Figure 1

This concept was used to create the world's first drippers. A small tube wrapped around the pipeline ensured the necessary pressure loss to deliver a dripped supply of water at a certain flow rate.

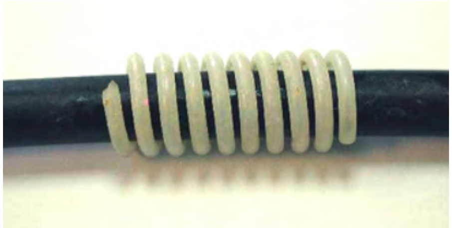

Figure 2. The world's first dripper.

The dripper concept evolved from a tube wrapped around the dripline into the first moulded dripper manufactured by Netafim in 1966. The laminar flow barrel-shaped dripper consisted of a cylindrical tube inserted into the dripline. The dripper created pressure loss and facilitated laminar flow.

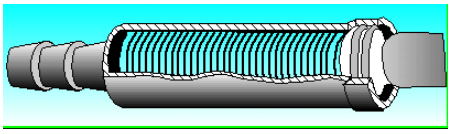

Figure 3. Laminar flow barrel-shaped dripper.

Laminar versus turbulent flow

The shift from laminar to turbulent flow in drippers was an important one for the longevity of drippers. Laminar flow and turbulent flow are opposites, as illustrated below.

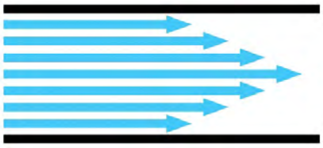

Figure 4. Laminar flow.

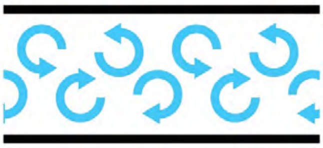

Figure 5. Turbulent flow.

To create turbulence, teeth were designed and added to the dripper's flow path to form a labyrinth in 1970. (See figure 6 below) The addition of teeth to dripper labyrinths creates turbulence, resulting in a turbulent, rather than laminar, flow. This keeps particles in suspension, allowing them to pass through the dripper. (See figure 7 below)

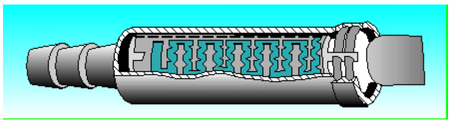

Figure 6.

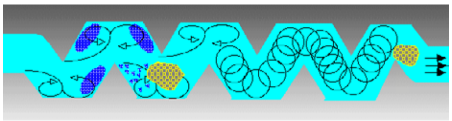

Figure 7.

An easy way to understand the efficiency of laminar versus turbulent flow in keeping a dripper clean, is to think of the efficiency of modern washing machines. Laminar flow can be compared to soaking washing in a bucket, while turbulent flow can be compared to the torrent activity of a washing machine.

Modern Drippers

Drippers have rapidly evolved since the basic concept of the first dripper. From the first wrapped-tube and later barrel-shaped drippers to drippers that are specifically designed to overcome challenges in the field and deliver exactly the water and nutrients required to the root zone of the plant at the right time.

Today, drippers are boat-shaped rather than barrel shaped and welded into the inside of a driplines. (See figures 9 and 10 below)

Figure 9. A modern dripper.

Figure 10. A modern dripline.

To understand the interaction between the engineering features within a dripper and the pressure difference from the inlet of the dripper flow path to its outlet, let's consider the equation below.

Equation 1

$$P = (K*N*Q^{2}) / (254*(W*D)^{2)}$$

- P - Pressure differential through the labyrinth (m)
- K - Turbulence coefficient
- W - Width of the labyrinth water passage (mm)
- D - Depth of the labyrinth water passage (mm)
- N - Number of teeth in the labyrinth
- Q - Labyrinth flow rate (ℓ/h)

Through analysis of this equation it becomes clear that pressure loss comprises of both turbulence and friction loss.

In fact:

Pressure loss =
turbulence + friction loss

It is important to understand the interaction between these two aspects. The less turbulence the dripper can create, the more it has to resort to friction loss to create the necessary pressure loss. Therefore, the more turbulence (the greater the value of K), the better the dripper is at keeping clean.

Turbulence Coefficient (K) – the greater, the better

The value of K is determined by certain dripper design factors and dripper dimensions. The greater the depth and the width of a dripper labyrinth, the better.

- A wider and deeper labyrinth results in a higher K value. The shorter the length of the dripper labyrinth, the better.
- A shorter labyrinth has less teeth, resulting in a higher turbulence coefficient (K).
- The less teeth we have to use to create the necessary friction loss, the better.

Labyrinth depth and width – the greater, the better

If we apply the dimensions of example drippers to equation 1 above, it is easy to understand the role these dimensions play in the value of K.

	Example dripper A	Example dripper B
Flow Rate	1.0 l/h	1.0 l/h
Number of Teeth	44	44
Pressure Difference	1.0 bar	1.0 bar
Labyrinth Width	0.60 mm	0.61 mm
Labyrinth Depth	0. 59 mm	0. 60 mm

A. If we applied these measurements to Equation 1, the calculated value of K is **7.2**.

B. An increase of only **0,01mm** in the width and depth of the labyrinth brings this value to **7.7**.

Labyrinth length – the shorter, the better

A shorter labyrinth has less teeth and finally results in a greater turbulence coefficient (K). Using the same example dripper as above, 44 teeth brings us to a K-value of **7.2**. If the number of teeth is however increased (longer labyrinth) to **82**, it brings us to a K-value of **3.9**.

Another important factor impacts dripper quality. This is the design and manufacturing of the dripper. If the design and manufacture of a dripper labyrinth are not optimal, the turbulence coefficient (K) will be lower and the dripper will need to resort to friction loss to achieve the required pressure loss. This means that it will be necessary to increase the number of teeth and therefore the length of the labyrinth and/or to narrow the height and width of the labyrinth.

Using the same example dripper as above and once again applying it to equation one, the dripper with a pressure loss of 1.0 bar will bring us to a K-value of **7.2**. If the pressure loss however increases, something that can only be affected by the quality of design and/or manufacture, the turbulence coefficient increases. If the pressure loss is increased to 1.2 bar, the turbulence coefficient becomes **8.7**.

Figure 11 below demonstrates different dripper labyrinth designs with progressively increasing turbulence from left to right. The value of K (turbulence coefficient) is lowest on the left and highest on the right.

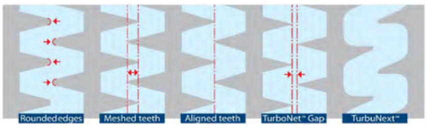

Figure 11. Labyrinth designs with increasing turbulence from left to right.

If the teeth of a labyrinth do not have razor sharp edges, more teeth must be added to the labyrinth to create more friction loss as rounded edges create less turbulence than sharp edges. This will not only lower the turbulence coefficient further but may possibly also mean that the filtration area would be smaller. The sharpness of the labyrinth edges will depend on the standard of the injection moulding process as well as the process of welding the dripper into the driplines.

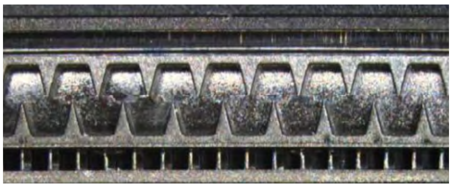

Figure 12 Razor-sharp teeth

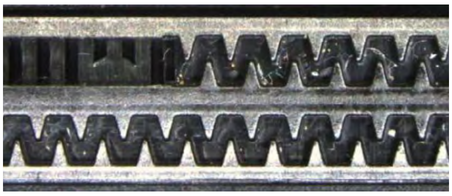

Figure 13 Rounded teeth

Effective Filtration

The purpose of filtration in an irrigation system, is to protect the emitter, and the efficiency of the entire system. There are several layers of filtration in an irrigation system, namely prefiltration, primary filtration and secondary filtration. The last line of filtration defence is however in the dripper itself. In all other layers of filtration, it is possible to clean filters by hand or backflush the filter to clean it. The dripper filter can however not be backflushed or cleaned by hand. Limited dirt removal from the outside of the dripper itself can be achieved by regularly flushing driplines. Even the most adequate dripper flushing will however not remove all of the dirt trapped by the dripper filter. As soon as the entire filtration area within the dripper is blocked by trapped dirt, the dripper will no longer function. This is why a dripper with a smaller filtration area will not last as long as a dripper with a larger filtration area.

The larger filtration area will take much longer to become fully blocked. Therefore, a bigger filtration area is conducive to dripper longevity. The longer a dripper needs to last, the larger filter area must be.

Dripper and Dripline Longevity

Dripline longevity is determined by the quality of materials used, as well as the wall thickness. The heavier the wall thickness, the longer the dripline will last. Dripper longevity, to put it simply, is determined by dripper size. The bigger the dripper, the longer it will last. A bigger dripper will make possible a bigger filter. The bigger the filter, the better. The filters in modern drippers cover almost the entire underside of the dripper (See figure 14). As a rule, bigger drippers are welded into heavier wall thicknesses and smaller drippers are welded into thinner wall thicknesses.

Dripline Wall Thickness Categories

Thin Wall Driplines (TWD)	Medium Wall Driplines (MWD)	Heavy Wall Driplines (HWD)
0.1mm to 0.4mm	0.5mm to 0.8 mm	0.9mm to 1.2 mm
1 to 3 seasons	4 to 9 seasons	10 or more seasons

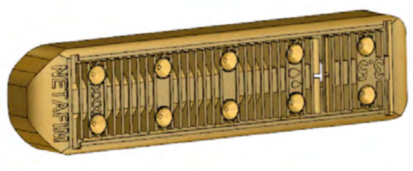

Figure 14. The filter area covers almost the whole underside of the dripper

Dripper Flow Rate

In a non-pressure compensating dripper, the flow rate of the dripper will change of the pressure at the inlet of the dripper changes. A lower pressure will cause a lower flow rate and a higher pressure a higher flow rate. The relationship between pressure and flow rate is explained in equation 2 below:

Equation 2

$$Q = K(P^X) \text{ sometimes written as } Q = A(P^B)$$

- Q = flow rate in litres per hour.
- K = Flow rate constant. A number that is connected to the flow rate. Sometimes called A if Q=AX (P^B). Not to be confused with turbulence coefficient K.
- P = Inlet pressure in metres.
- X = pressure exponent.Sometimes called B

An irrigation designer starts with the dripper and designs backwards through the driplines, submains, mainlines, until reaching the pump. On a flat irrigation block, the highest pressure will be at the corner of the irrigation block at the bottom left of Figure 15 below. The lowest pressure will be at the last dripper in the corner at the top right of Figure 15 below.

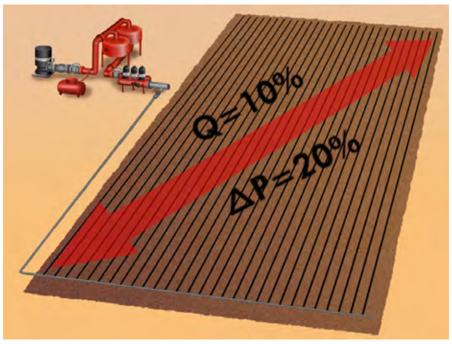

Figure 15.

The flow from every dripper may not vary by more than 10% across the entire irrigation block.

For a 1.0 ℓ/h dripper, the irrigation design must aim for:

- Max flow rate = 1.0 ℓ/h + 5% = 1.05 ℓ/h
- Min flow rate = 1.0 ℓ/h - 5% = 0.95 ℓ/h

Let's take a sample dripper with K equal to 0.316 and X equal to 0.5

If the pressure is 10 m, and we apply equation 2:

Q = 0.316 x 100.5 = 1.0 ℓ/h

Remember, the flow from every dripper may not vary by more than 10% across the entire irrigation block. When the maximum and minimum flow rates are applied to equation 2, we get the following pressures.

- Max flow rate = 1.05 ℓ/h = 0.316 x $11^{0.5}$
- Min flow rate = 0.95 ℓ/h = 0.316 x $9^{0.5}$

In other words:

- Max pressure = 11 metres
- Min pressure = 9 metres

In this case, when the pressure exponent is 0.5, a flow variation of 10% means a pressure variation of 20%. This pressure variation is called the pressure envelope. Pressure envelope = 11.0 m – 9.0 m = 2.0 m (ΔP in Figure 15)

When combined with the natural slopes of a field, the pressure envelope is used to size the dripline diameters and the submain diameters. In this case, where the pressure envelope is 2 m, pipes will be sized to absorb 2 m pressure loss.

In our next sample dripper, the exponent's value is reduced to 0.4.

If the pressure is 10 m, and we apply equation 2:

- Q = 0.398 x $10^{0.4}$ = 1.0 ℓ/h

Again, the flow from every dripper may not vary by more than 10% across the entire irrigation block. When the maximum and minimum flow rates are applied to Equation 2, we get the following pressures.

- Max flow rate = 1.05 ℓ/h = 0.398 x $11.3^{0.4}$
- Min flow rate = 0.95 ℓ/h = 0.398 x $8.8^{0.4}$
- **Flow variation = 10%**

- Max pressure = 11.3 metres
- Min pressure = 8.8 metres
- **Pressure variation = 2.5 m / 10 m = 25%**

Pressure envelope = 11.3 m – 8.8 m = 2.5 m
In this case, where the pressure envelope is 2.5 m, pipes will be sized to absorb 2.5 m pressure loss.

When the exponent was 0.5, we had a pressure envelope of 2.0 m in which to size the pipes. When the exponent reduced to 0.4, the pressure envelope increased to 2.5 m to size the pipes. As 2.5 m is larger than 2.0 m, the pipes absorbing this pressure loss may be smaller and less costly. In other words, the lower the value of the dripper exponent, the lower the cost of the pipes. We can therefore conclude that - the lower the pressure exponent (the value of x), the better.

Now let us look at sizing the pipes to keep head loss at 2.0m, one with a dripper with an exponent of 0.5 and another dripper with an exponent of 0.4.

We have already seen in the example above that an exponent of 0.5 applied to a 10% variation in flow results in a 2.0m pressure envelope. If we size the pipes to keep head loss at 2.0m when the pressure exponent is 0.4, we can make the following calculations:

- Max flow rate = 1.04 ℓ/h = 0.316 x $11^{0.4}$
- Min flow rate = 0.96 ℓ/h = 0.316 x $9^{0.4}$
- Flow variation = 8%

The flow variation has improved from 10% to 8%, and we can gather that:
The lower the pressure exponent (the value of x), the better. A lower pressure exponent allows us to use smaller pipes, resulting in decreased costs. The lower pressure exponent also translates to lower flow variation.

Take note that a lower pressure exponent, when combined with the head loss value (KD), may allow us to use longer laterals with a low-pressure exponent.

In pressure-compensating drippers, the pressure exponent is always zero. The lower the exponent, the less effect a change in pressure will have on the flow rate. In a pressure compensating dripper, a change in pressure results in no change in flow rate and the value of the exponent is zero. Remember, anything to the power of zero equals one. This means that the K-value (flow rate constant) becomes the dripper flow rate.

- 2.0 ℓ/h = $2.000 \times 10^{0.0} = 2.000 \times 1$
- 1.5 ℓ/h = $1.500 \times 5^{0.0} = 1.500 \times 1$
- 0.7 ℓ/h = $0.700 \times 25^{0.0} = 0.700 \times 1$

The impact of KD

KD, or dripper local head loss, is the loss in pressure as a result of the dripper being in the dripline. Earlier in this article I mention friction loss. Dripline pressure loss is a combination of local head loss (KD) and friction loss.

Consider the diagrams in figure 16 below to understand the impact of the dripper in the dripline:

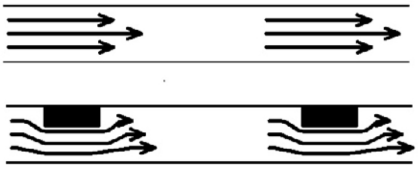

Figure 16

This is the first of the features that considers the driplines as well and not only the dripper. We must realise that a dripper in a dripline effectively blocks a part of the dripline. The dripper's mere presence impedes flow and increases pressure loss. The KD value describes the extent to which the dripper impedes the flow and increases pressure loss in the dripline. It is influenced by dripper size and pipe diameter. The KD of a dripper can be considered neither a disadvantage nor disadvantage. The KD value is typically between 0.1 and 1

It is often thought that smaller drippers should be used rather than larger drippers, as they have a lower KD. Is this however true? Not necessarily. You cannot consider the KD value in isolation. Larger drippers are better for several other reasons, as explained in this article. All factors must be considered to determine the best dripper for the job.

Let's consider the table below to recap the values that can be used in dripper comparison:

Value	Meaning	Range	Impact
K	Turbulence Coefficient	1 to 10	Higher is better
EFA	Filtration Area	10 mm2 to 100 mm2	Larger is better
X or B	Pressure Exponent	0.4 to 0.5 m (In non-PC drippers)	Lower is better
K or A	Flow Rate Constant		Impacted by value of K and X
KD	Local Head Loss	0.1 to 1	Cannot be viewed in terms of better or worse.

Having these values at their disposal, makes it easier for an irrigation designer or user to select the best dripper for the job.